



XXV. Note on a mode of maintaining tuning forks by electricity

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the formation and decomposition of the sulphates is evidently questionable, even from the results he obtained.

This paper is not of course meant as a criticism on Dr. Wright's work, which I have always admired for its accuracy, but merely gives a new interpretation of certain of his experimental results.

XXV. *Note on a Mode of maintaining Tuning Forks by Electricity.* By Prof. S. P. THOMPSON*.

ALL who have worked with self-maintained electric tuning-forks have met with the fact that these instruments as ordinarily arranged give a very irregular note, the pitch of which is continually slightly altering, and even those which are fairly constant in pitch are continually changing the phase of their vibrations. These changes of phase and of pitch render the electrically-sustained tuning-fork as usually constructed almost useless for acoustic work, and diminish the usefulness of the instrument for chronoscopic and electric applications. They appear to be due to a fact which is tolerably obvious to any one acquainted with the fundamental principles of the vibrations of elastic bodies, namely, that the impetus given by the electromagnet at each vibration is given at the wrong instant of the motion, namely at some other instant than that during which the fork is passing with maximum velocity through the position of zero displacement. In the older forms of electro-diapason constructed by Fessel and by Koenig†, the electromagnet was of horseshoe form, having poles outside the prongs of the fork; whilst in the more recent instruments by Koenig the electromagnet is of short cylindrical form, and placed between the prongs of the fork. The latter arrangement, which is preferable for several reasons electrical and mechanical, seems to have been first suggested by Lord Rayleigh‡. In the earlier form contact was made by a stylus, carried by the prong of the fork, dipping into the mercury cup: in the later form the stylus usually makes contact against a platinum-headed screw, almost exactly as does the interrupter of Wagner so common in electric bells. In either case contact is made at a very brief interval before the prong of the fork reaches its extreme elongation away from the pole of the electromagnet, and is broken at a slightly longer interval after the prong has passed its extreme elonga-

* Communicated by the Physical Society: read June 26, 1886.

† *Vide* Helmholtz, 'Sensations of Tone,' Ellis's edition of 1875, p. 178.

‡ 'Theory of Sound,' vol. i. p. 56.

tion, the difference arising from the elasticity of the stylus, and the necessary imperfection of the contact until a certain actual contact-pressure has been attained. There is also a certain retardation in the electro-magnetic pull behind the instant of greatest current, owing to the self-induction of the circuit and the mutual induction between the coil and its core. But if the core be short, and laminated, and of good iron, and if the resistance of the circuit be considerable in proportion to its coefficient of self-induction, the retardation of phase in the periodic electromagnetic impulses will not be of any great importance. Lord Rayleigh remarks* that if the magnetic force depended only on the position of the fork the phase might be considered to be 180° in advance of that of the fork's own vibration. That is to say, considering a displacement of the fork toward the electromagnet positive, the maximum force occurs when the displacement is a negative maximum. But, adds Lord Rayleigh, the retardation due to self-induction and imperfect contact reduces this advance. Lord Rayleigh further remarks that if the phase-difference be reduced to 90° the force acts in the most favourable manner, and the greatest possible vibration is produced. He might have added that in this case the tendency to produce phase-change is the least possible. He suggested as a means of producing any desired retardation, the use of a stylus attached not to the prong itself, but to the further end of a light straight spring carried by the fork.

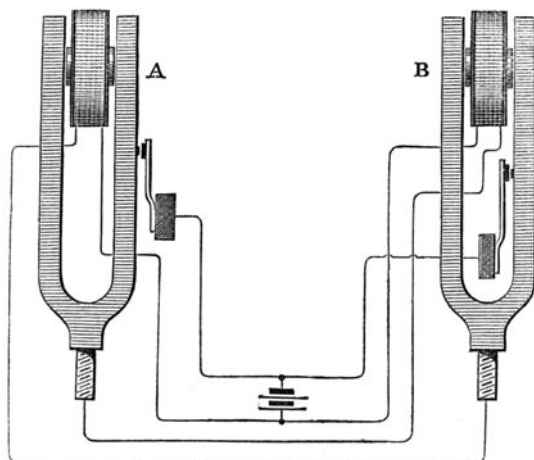
It seems to the present writer, that a better way to secure the proper timing of the impulses is to be found in the suggestion which he now makes, and which arose in his mind after considering the difference of phase which exists between two dynamo-electric machines associated together. Let two forks in unison with one another be provided, and let each act as interrupter to the other, but not to itself; the electromagnet of each being included in the circuit of the other's contact-points. One battery will suffice for the two, as they will not both make contact at the same time.

Fig. 1 shows the proposed arrangement. The forks when started will settle down to a difference of phase corresponding to an almost exact quarter of a period.

Fork B is arranged, as shown in fig. 1, so that it makes contact at the inward stroke at the point when its displacement is at the positive maximum; fork A makes its contact at the outward stroke when its displacement is at the negative maximum.

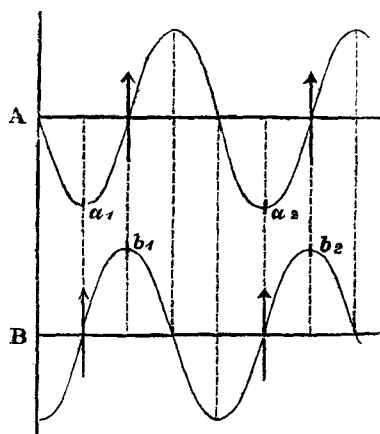
* *Op. cit.* p. 59.

Fig. 1.



Reference to figure 2 will elucidate the phase relations. In this figure the upper curve relates to fork A and the lower to fork B. Positive values of the ordinates relate to positive displacements in the sense of approach to the electromagnet.

Fig. 2.



When A has moved through $\frac{1}{4}$ of its cycle of movements, and the displacement is a negative maximum a_1 , it makes contact for B's electromagnet, which gives a momentary im-

pulse just as B has phase 0° . A quarter of a period later B makes contact (b_1), and gives an impulse to A just when A's phase is 0° . The arrows indicate the instant and direction of the forces. It is assumed that the retardation due to self-induction is small, as compared with the period of the forks; and this may easily be made so, firstly, by employing only short internal electromagnets with laminated cores, and, secondly, by interposing sufficient inductionless resistance in the circuit.

Another point of some importance in the construction of electrically sustained forks is that the contacts should be very firm, and should be made much nearer the hilt of the fork than is usual in these instruments. When the stylus is near the outward end of the prong there is much greater amplitude of motion at the contact than is really requisite. A pin of platinum secured to the prong at about 5 centimetres from the point of bifurcation, making contact against a platinum-faced strip of German silver, half a millimetre in thickness, to serve as a spring, will answer the purpose for forks of ordinary size.

A common imperfection in the electro-diapason as usually constructed is the method of mounting the fork. Its shank is held with nut and washer to a block of wood or metal, which is then secured to a stand by a single bolt or screw which runs at right angles to the shank and to the planes of vibration of the prongs. The defect of this mounting is that the fork can shift a little round the bolt, and is liable to become set with one prong nearer one face of the electromagnet than the other prong is to the other face. This often results in the occurrence of actual rattling contacts between the fork and the electromagnet, as well as in derangements of the adjustment of the working contacts. It also gives rise to another kind of difficulty: if one prong is nearer to the electromagnet than the other is, there will be a tendency for the fork to vibrate as a whole around the bolt or frame upon which it is mounted, and this will give rise to slow alternations of good and bad contacts, producing on the sound an effect not unlike that of beats. Either the bolt which secures the fork to its mounting should lie in the plane of the vibrations, or else it should be replaced by a more substantial species of mounting.